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**AIRCRAFT NAVIGATIONAL ASSISTANCE METHOD AND  
CORRESPONDING DEVICE**

5 The invention relates to a method and a device for assisting navigation.

10 The field of the invention is that of assistance with aerial navigation and aerial safety and relates more particularly to assistance with the monitoring of the guidance of an aircraft along a trajectory within the framework of automatic flight control.

15 It may involve a descent trajectory or climb trajectory. In what follows, a descent trajectory will be taken as an exemplary trajectory, and an airplane will be taken as an exemplary aircraft. Such a trajectory 1 represented in figure 1 and called the vertical profile consists of a succession of rectilinear segments and is decomposed into two parts:  
20 a first part 10 during which the airplane is relatively free and which may therefore be optimized by adopting a preset speed and a thrust making it possible to minimize the consumption of fuel and a second part 11 for preparing the airplane for approach and for landing  
25 on a runway 12 during which the airplane must comply with certain parameters relating to altitude, speed and horizontal course by adopting a constrained speed and a constrained slope.

30 An airplane descent trajectory is computed in reverse starting from the configuration of the airplane on landing, then by backtracking and by establishing from point 2 to point 2 the corresponding speed preset and thrust preset until the point at which the descent  
35 begins or "TOD", the acronym standing for "Top of Descent".

Once this profile has been established by the flight management system (FMS) on the basis of constraints

given by the air traffic controllers, the flight management system will give orders to the automatic pilot to join up with this profile and hold there, these orders being established as a function of control  
5 laws and of speed and thrust presets specific to the profile segment.

A distinction is made between the laws which determine the control of the elevators as a function of presets  
10 for speed (SPD), for vertical path (VPATH) or for vertical speed (VS) and the laws which determine the control of thrust and which are established as a function of presets for thrust (THR) or for speed (SPD). These laws are combined together and the  
15 resulting pairs of laws associated with guidance submodes, make it possible to establish the orders which will allow the aircraft to join up with (or stated otherwise capture) the profile segment or to hold there while complying with certain constraints.

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From the above, the zone in which it is possible to capture the profile by applying a transition between the guidance submode which the airplane is in and the guidance submode adapted to the following of the  
25 profile segment to be captured is designated as the zone of capture about the profile. Outside of this zone a guidance submode making it possible to join up with this capture zone as quickly as possible is applied.

30 This capture zone 3 represented in figure 2 may be defined as a band of diameter  $D$ , fixed or depending only on the speed, centered on the profile 1.

However these definitions take no account of the  
35 differences in particular between a flight at high altitude and high ground speed (at the start of a descent for example) and a flight at low altitude and low ground speed (during for example the preparation for the approach procedure), as well as the corollaries

such as flights at low altitude and high ground speed.

Thus for a flight at high altitude and/or at high speed, the capture zone is too restricted and the capture of the intended profile segment is too fast in particular for the comfort of the passengers; likewise for a flight at low altitude and/or at low speed, the capture zone is too wide and the capture of the intended profile segment is too lengthy in the sense that part of this capture time could have been devoted to another mode of flight and in particular to a faster capture with a more fuel-economical mode of flight such as for example the "airmass" mode.

Finally, the execution of the orders by the automatic pilot do not always make it possible to ensure the comfort of the passengers or to adopt a suitable mode of flight, during the capture of the profile.

It is known that, in order to ensure the comfort of the passengers, the movements of the aircraft must not lead to the vertical acceleration factor exceeding a certain threshold, for example equal to 0.1 g, g being the terrestrial acceleration ( $g = 9.81 \text{ m/s}^2 = 32.1725 \text{ ft/s}^2$ ). This factor must not be exceeded during capture either.

As a result, in order to ensure the comfort of the passengers, it is necessary to force the capture of the profile through trajectories subject to constrained load factors. The shape of the trajectory making it possible to preserve a constant vertical acceleration factor during capture is a parabola tangential to the profile.

To ensure the comfort of the passengers, it is also necessary to avoid big variations in thrust.

An important aim of the invention is therefore to

choose a capture zone that is better adapted to the comfort of the passengers and to fastness of capture than in the prior art.

5 To achieve these aims, the invention proposes a method of automatic navigation assistance for an aircraft, principally characterized in that a capture zone being a zone in which the aircraft can capture a predetermined vertical profile segment by applying a  
10 transition between the guidance submode which the aircraft is in and the guidance submode adapted to the following of the vertical profile segment to be captured, it comprises the step consisting in determining the width of the capture zone as a function  
15 of the height of the vertical profile to be captured and of the speed which the aircraft has when plumb with this height when the aircraft is not on the profile or at this height when the aircraft is on the profile.

20 A subject of the invention is also a device for automatic navigation assistance for an aircraft comprising at least one program memory, characterized in that the program memory comprises a program for computing the width of a capture zone, a capture zone  
25 being a zone in which the aircraft can capture a predetermined vertical profile segment by applying a transition between the guidance submode which the aircraft is in and the guidance submode adapted to the following of the profile segment to be captured, the  
30 width of the capture zone being calculated as a function of the height of the vertical profile to be captured and of the speed which the aircraft has when plumb with this height when the aircraft is not on the profile or at this height when the aircraft is on the  
35 profile.

Other characteristics and advantages of the invention will become apparent on reading the detailed description which follows, given by way of non limiting

example and with reference to the appended drawings in which:

figure 1 already described diagrammatically represents  
5 a vertical profile,

figure 2 already described diagrammatically represents  
a capture zone according to the state of the art,

10 figure 3 diagrammatically represents a capture zone  
according to the invention,

figure 4 diagrammatically represents a device for  
assisting navigation according to the invention.

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The problem posed is to determine the capture zone and  
more precisely to determine it in an optimal manner as  
a function of the dynamics of the airplane and of the  
comfort of the passengers.

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More precisely, this involves determining this capture  
zone in such a way that it is wider for a flight at  
high altitude and/or high speed and less wide for a  
flight at low altitude and/or at low speed.

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The method according to the invention is based on the  
computation of the width of the capture zone also  
referred to as the margin, as a function of the height  
of the vertical profile to be captured and of the  
30 ground speed that the airplane has when plumb with this  
height when the aircraft is not on the profile or at  
this height when the aircraft is on the profile.

According to a particular embodiment of the invention,  
35 this function is determined from the law regarding the  
total mechanical energy, such that  $E_t = E_c + E_p$ .

$E_t$ ,  $E_c$  and  $E_p$  respectively being the total energy, the  
kinetic energy and the potential energy of the

airplane.

As represented in figure 3, by designating the ground speed that the airplane has on the profile at the height  $h$  or plumb with this height by  $v$ , its mass by  $m$ , the height of the upper bound of the capture zone by  $h'$  and the height of the lower bound by  $h''$ , and by defining the equivalent total height  $h_t$  arising from the total energy, we put:

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$$E_t = mgh_t = \frac{1}{2}mv^2 + mgh,$$

$$\text{i.e. } h_t = \frac{v^2}{2g} + h$$

15

According to an embodiment of the invention, the margin is then expressed according to a function of the total height by considering a safety height  $h_s$  and an adaptation constant  $K$  varying according to the characteristics of the airplane:

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$$\Delta h = h' - h = h - h'' = h_s + \frac{1}{K}h_t = h_s + \left[ h + \frac{v^2}{2g} \right] \frac{1}{K}$$

25  $K$  allows  $\Delta h$  to vary between  $h_s$ , for a flight at low altitude and low speed, and a limit height for a flight at high altitude and high speed, regardless of the ground speed  $v$  and the height  $h$ .

30 The method described is implemented in an onboard device for assisting the navigation of an aircraft. An example of this device 100 is represented in figure 4. It comprises in a conventional manner one or more microprocessors 101 coupled to a program memory 102 of ROM type for example, to a work memory 103 of RAM type  
35 for example and to one or more memories 104 of ROM type

for example for the storage of the vertical profile to  
be captured, as well as circuits 105 for transferring  
data between these various elements. The program memory  
102 contains the program that runs the method, in the  
5 form of source code, whereas the work memory 103  
comprises registers that can be updated for the storage  
of the results of the computations. This equipment 100  
also comprises a communication interface 106 for  
allowing the exchange of data with devices such as for  
10 example with a user interface 107, with sensors, etc.

These elements are for example included in a flight  
management system (FMS). They may also be included in  
the form of dedicated integrated circuits, designed to  
15 implement the method.